MDOT
Michigan Department of Transportation

OFFICE MEMORANDUM

DATE: May 14, 2004

TO: Region Engineers
               Region Delivery Engineers
               TSC Managers
               Resident/Project Engineers
               Region Construction Engineers

FROM: Larry E. Tibbits
               Chief Operations Officer

               John C. Friend
               Engineer of Delivery

SUBJECT: Bureau of Highway Instructional Memorandum 2004-17
               Michigan Test Method 314, Theoretical Maximum Specific Gravity
               of HMA Paving Mixtures and Michigan Test Method 315, Bulk Specific
               Gravity and Density of Compacted HMA Mixtures Using Saturated Surface-
               Dry Specimens

The referenced test methods have been modified to more accurately state the testing procedures and to promote uniformity during the processes. The revised test methods are the result of a coordinated review effort with MDOT and industry testing personnel.

These revised methods (attached) are to be implemented for the 2004 construction season and will be incorporated into the MDOT Michigan Test Methods when that publication is updated later this year.

It is recommended that individuals performing these tests review these methods thoroughly both prior to and during the testing process to become familiar with the changes. (Note: Figure 1 of MTM 314 replaces Attachment 3 of BOH IM 2004-07.)

Please refer all questions regarding these modifications to the Construction and Technology Support Area's Construction Paving Unit or to Judy Browning, co-chair HMA Training Committee 231-941-1986 ext. 304.

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Chief Operations Officer   Engineer of Delivery

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MICHIGAN TEST METHOD
FOR
THEORETICAL MAXIMUM SPECIFIC GRAVITY
OF HMA PAVING MIXTURES

1. Scope

    1.1   This test method covers the determination of the theoretical maximum specific gravity and density of uncompacted HMA paving mixtures at 77 °F (25 °C).

    1.2   The values stated in SI units are to be regarded as the standard.

2. Referenced Documents

    2.1   *ASTM Standards*:
    D979   Test Methods for Sampling HMA Paving Mixtures[2]
    D 2041   Standard Test Method for Theoretical Maximum Specific Gravity and Density of HMA Paving Mixtures[2]
    D4311   Practice for Determining Asphalt Volume Correction to a Base Temperature[2]
    E 1   Specification for ASTM Thermometers[3]
    E 12   Terminology Relating to Density and Specific Gravity of Solids, Liquids, and Gases[4]

3. Terminology

    3.1   The terms specific gravity and density used in this test method are in accordance with Terminology E 12.

    3.2   *Definitions:*

        3.2.1   *Density, as determined by this test method* - the mass of a cubic meter of the material at 77°F (25 °C) in SI units, or the mass of a cubic foot of the material at 77°F (25 °C) in inch-pound units.

        3.2.2   *Residual pressure, as employed by this test method* - the pressure in a vacuum vessel when vacuum is applied.

        3.2.3   *Specific gravity*, as determined by this test method - the ratio of a given mass of material at 77°F (25 °C) to the mass of an equal volume of water at the same temperature.

4. Summary of Test Method

    4.1   A weighed sample of HMA paving mixture in the loose condition is placed in a vacuum vessel. Sufficient water at a temperature of 77 ± 1.8°F (25 °C ± 1.0 °C) is added to completely submerge the sample. Vacuum is gradually applied to reduce the residual pressure in the vacuum vessel to 25 +/-2 mm of Hg and then held for 15 +/- 2 min. At the end of the vacuum period, the vacuum is

gradually released. The volume of the sample of paving mixture is obtained by immersing the vacuum container with sample into a water bath and weighing. At the time of weighing, the temperature is measured as well as the mass. From the mass and volume measurements, the specific gravity or density at 77°F (25° C) is calculated

5. Significance and Use

    5.1   The theoretical maximum specific gravities and densities of HMA paving mixtures are intrinsic properties whose values are influenced by the composition of the mixtures in terms of types and amounts of aggregates and HMA materials.

            5.1.1   They are used to calculate values for percent air voids in compacted HMA paving mixtures.

            5.1.2   They provide target values for the compaction of paving mixtures.

            5.1.3   They are essential when calculating the amount of bitumen absorbed by the internal porosity of the individual aggregate particles in a HMA paving mixture.

6. Apparatus

    6.1   *Vacuum container,* for weighing in air and water shall be a 4500 mL metal vacuum pycnometer with a clear plastic lid.

    6.2   *Balance*, with ample capacity, and with sufficient sensitivity to enable the specific gravity of samples of uncompacted paving mixtures to be calculated to at least four significant figures, that is, to at least three decimal places. It shall be equipped with a suitable apparatus to permit weighing the specimen in water while suspended from the center of the scale. Use wire or fish line of the smallest practical size to suspend the specimen holder. Do not use chains, strings, or sash cords. The balance shall conform to Specification D 4753 as a class GP2 balance.

    6.3   *Vacuum pump or water aspirator*, capable of evacuating air from the vacuum container to a residual pressure of 25 +/- 2 mm of Hg.

            6.3.1   When a vacuum pump is used, a suitable trap of one or more 1000 mL filter flasks, or equivalent, shall be installed between the vacuum vessel and vacuum source to reduce the amount of water vapor entering the vacuum pump.

    6.4   *Residual pressure manometer[5] or calibrated digital absolute pressure gage (either)*, must be connected directly to the vacuum vessel at the end of the vacuum line and be capable of measuring residual pressure down to 25 +/- 2 mm of Hg.

NOTE 1 - An example of a correct arrangement of the testing equipment is shown in Fig. 1.

NOTE 2 - Residual pressure in the vacuum vessel measured in millimeters of mercury, is the difference in the height of mercury in the Torricellian vacuum leg of the manometer and the height of mercury in the other leg of the manometer that is attached to the vacuum vessel.

6.5 *Manometer or vacuum gauge*, suitable for measuring the vacuum being applied at the source of the vacuum. This is required to check the reading given by the residual pressure manometer attached directly to the vacuum vessel.

NOTE 3 - The Torricellian vacuum leg of the manometer occasionally acquires one or more bubbles of air that introduce error into the residual pressure reading. By the addition of the vacuum gage, this error can often be quickly detected by the differences between two vacuum measurements.

6.6 *Thermometers*, calibrated liquid-in-glass thermometers of suitable range with subdivisions and maximum scale error of 0.9 °F (0.5 °C), or any other thermometric device of equal accuracy, precision and sensitivity shall be used. Thermometers shall conform to the requirements of Specification E 1.

6.7 *Water Bath,* when weighing-in-water, must be suitable for immersion of the suspended container with its de-aerated sample and capable of maintaining a constant temperature between 68 °F (20 °C) and 86 °F (30 °C). The use of an overflow outlet is mandatory.

6.8 *Bleeder valve*, attached to the vacuum train to facilitate adjustment of the vacuum being applied to the vacuum vessel and the slow release of vacuum pressure.

6.9 *Mechanical agitation device,* capable of applying a gentle but consistent agitation of the sample. This device shall be equipped with a means of firmly anchoring the container so that it does not move on the surface of the device.

6.10 *Protective gloves*, used when handling glass equipment under vacuum.

7.   <u>Sampling</u>

7.1 Obtain the sample in accordance with Test Methods D979.

7.2 The size of the sample shall conform to the following requirements. Sample Sizes greater than about two thirds of the volume of the container shall be tested in portions with none of the portions tested being less than 1250 g.

Nominal Maximum Aggregate Size

in. (mm)	Minimum Sample Size, g
1 (25.0) or greater	2500
¾ (19.0) or smaller	2000

8. Calibration of Pycnometer

8.1 Calibrate the container by accurately determining the mass of the container dry (B) and in water(E) at $77° \pm 1.8°F$ (25 °C $\pm$ 1.0 °C). Verify the dry weight (within $\pm$ 0.1g) daily.

8.2 The equipment must be kept clean.

9. Procedure

9.1 Separate the particles of the sample of paving mixture by hand, taking care to avoid fracturing the aggregate, so that the particles of the fine aggregate portion are not larger than 1/4 inch (6.3 mm).

9.2 Cool the sample to room temperature, place it in the container and weigh. Designate the net mass of the sample as sample and bowl weight in air (A). Add water at a temperature of approximately 77°F (25°C) to cover the sample with a minimum of 1 inch of water. The water level surface should be at least 1 ½ inches from the top of the pycnometer bowl.

9.3 Remove air trapped in the sample by starting the agitation and gradually increasing the vacuum until the residual pressure manometer reads 25 +/- 2 mm of Hg. Maintain this residual pressure for 15 +/- 2 minutes. Agitate the container and contents during the vacuum period continuously by a mechanical device.

9.4 At the end of the vacuum period, gradually release the vacuum using the bleeder valve. Suspend the container and contents in the water bath and determine the mass after 10 minute $\pm$ 1 minute immersion. Record the mass of the sample and bowl weight in water (D) at 77 °F (25 °C).

10. Calculations

10.1 Calculate the theoretical maximum specific gravity of the sample at 77 °F (25 °C) as follows:

Sample and Bowl Wt. in Air, grams	A	_____
Bowl Wt. in Air, grams	B	_____
Sample Wt. in Air, grams	C=A-B	_____
Sample and Bowl Wt. in Water, grams	D	_____
Bowl Wt. in Water, grams	E	_____
Sample Wt. in Water, grams	F=D-E	_____
Volume, cc	G=C-F	_____
Gmm	C/G	_____

10.2 If the sample was tested in several portions, report the weighted average maximum specific gravity for all portions tested.

11.   Report

      11.1   *Report the following information*:
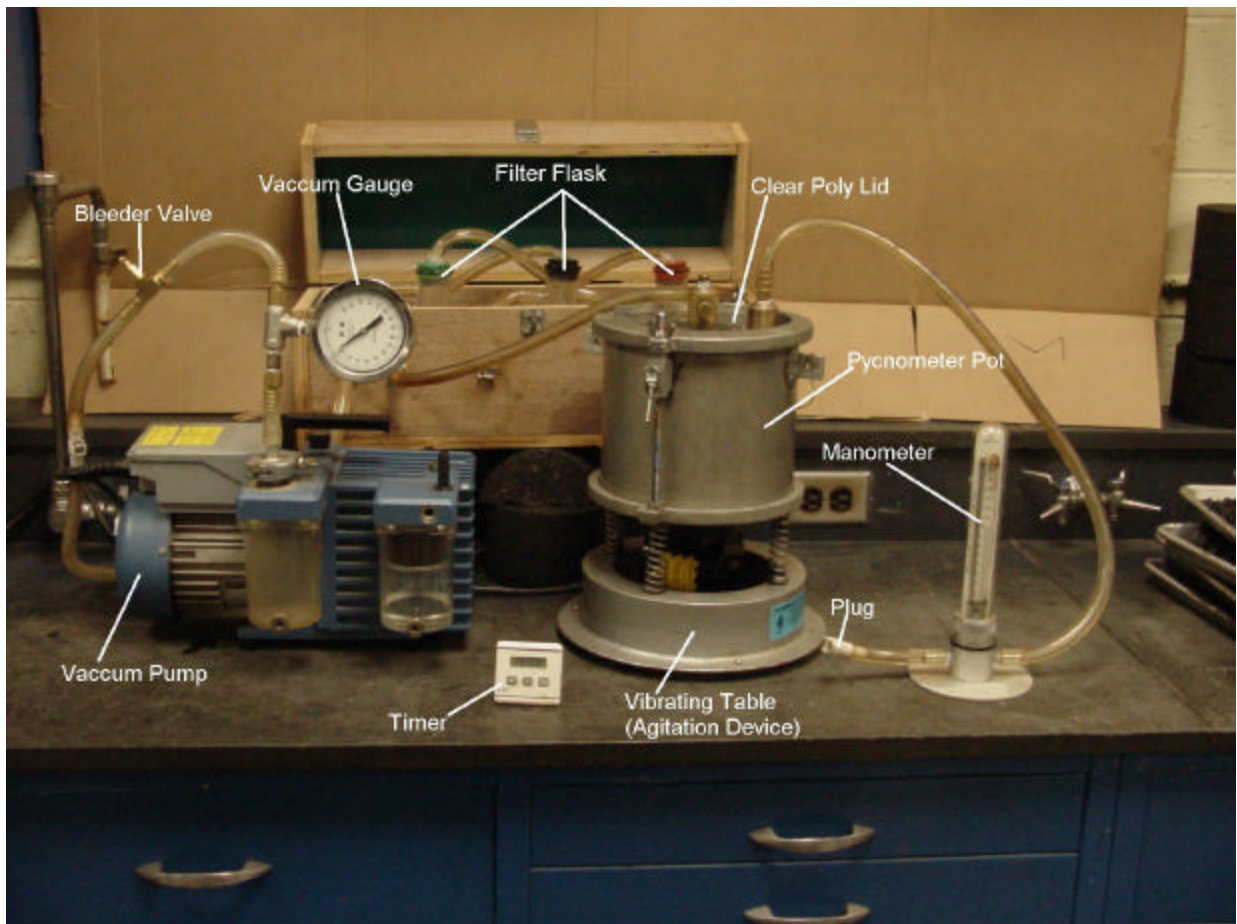   - Specific gravity of the mixture to the third decimal place
           - Type of mixture,
           - Size of sample,
           - Number of samples.

[2]Annual Book of ASTM Standards, Vol 04.03.
[3]Annual Book of ASTM Standards, Vol 14.03.
[4]Annual Book of ASTM Standards, Vol 15.05.
[5]Sargent Welch, 39745 Gauge-Vacuum, Mercury Pre-filled (or equivalent).

Figure 1

MICHIGAN TEST METHOD
FOR
BULK SPECIFIC GRAVITY AND DENSITY OF COMPACTED HMA MIXTURES USING SATURATED SURFACE-DRY SPECIMENS

1. Scope

    This test method covers the determination of bulk specific gravity and density of specimens of compacted HMA mixtures.

    1.1.1 This test method should be used only with dense graded or practically nonabsorptive compacted mixtures.

    1.1.2 This test method should not be used with samples that contain open or interconnecting voids. Test Method D1188 should be used for these samples.

    1.2 The values stated in SI units are to be regarded as the standard.

2. Referenced Documents

    2.1 *ASTM Standards*:
    C 670   Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials[2]
    D 979   Practice for Sampling HMA Paving Mixtures[3]
    D 1188   Standard Test Method for Bulk Specific Gravity and Density of Compacted Bituminous Mixtures Using Coated Samples.
    D 1461   Test Method for Moisture or Volatile Distillates in HMA Paving Mixtures[2]
    D 2726   Standard Test Method for Bulk Specific Gravity and Density of Compacted HMA Mixtures Using Saturated Surface-Dry Specimens[3]
    D 3203   Test Method for Percent Air Voids in Compacted Dense and Open HMA Paving Mixtures[3]
    D 3666   Practice for Evaluating and Qualifying Agencies Testing and Inspecting HMA Paving Material[3]
    D 4753   Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Testing Soil, Rock, and Related Construction Materials[4]

3. Terminology

    3.1 Descriptions of Terms:

    3.1.1 *Bulk density* - as determined by this test method, the mass of a meter cubed of the material at 77 °F (25 °C).

    3.1.2 *Bulk specific gravity* - as determined by this test method, the ratio of the mass of a given volume of material at 77 °F (25 °C) to the mass of an equal volume of water at the same temperature.

4. Summary of Test Method

4.1 The specimen is immersed in a water bath at 77 °F (25 °C). The mass under water is recorded, and the specimen is taken out of the water, blotted quickly with a damp towel, and weighed in air. The difference between the two masses is used to measure the mass of an equal volume of water at 77 °F (25 °C).

4.2 This test method provides guidance for determination of the oven dry or thoroughly dry mass of the specimen. The bulk specific gravity is calculated from these masses. Then the density is obtained by multiplying the specific gravity of the specimen by the density of the water.

5. Significance and Use

5.1 The results obtained from this test method can be used to determine the unit weight of compacted dense HMA mixtures and in conjunction with Test Method D 3203, to obtain percent air voids. These values in turn may be used in determining the relative degree of compaction.

5.2 Since specific gravity has no units, it must be converted to density in order to do calculations that require units. This conversion is made by multiplying the specific gravity at a given temperature by the density of water at the same temperature.

NOTE 1 -The personnel and equipment used in performing this test can be evaluated in accordance with Practice D 3666.

6. Apparatus

6.1 Balance, with ample capacity, and with sufficient sensitivity to enable bulk specific gravities of the specimens to be calculated to at least four significant figures, that is, to at least three decimal places. It shall be equipped with a suitable apparatus to permit weighing the specimen while suspended in water. Use wire or fish line of the smallest practical size to suspend the specimen holder. Do not use chains, strings, or sash cords. The balance shall conform to Specification D 4753 as a class GP2 balance.

NOTE 2 - Since there are no more significant figures in the quotient (bulk specific gravity) than appear in either the dividend (the mass of the specimen in air) or in the divisor (the mass of the volume of water equal to the volume of the specimen, obtained from the difference in weight of the saturated surface-dry specimen in air and in water), this means that the balance must have a sensitivity capable of providing both mass values to at least four figures. For example, a sensitivity of 0.1 g would provide four significant figures for mass in the range from 100.1 g to 999.9 g.

6.2 Water Bath, for immersing the specimen in water while suspended, equipped with an overflow outlet for maintaining a constant water level. The use of an overflow outlet is mandatory.

7. Sampling

   7.1   Specimens may be either laboratory-molded HMA mixtures or from HMA pavements.

   7.2   Obtain field samples in accordance with Practice D 979.

   7.3   Pavement specimens shall be taken from pavements with a core drill, diamond or a carborundum saw, or by other suitable means.

8. Test Specimens

   8.1   Size of Specimens - it is recommended, (1) that the diameter of cylindrically molded or cored specimens, or the length of the sides of sawed specimens, be at least equal to four times the maximum size of the aggregate; and (2) that the thickness of specimens be at least one and one half times the maximum size of the aggregate.

   8.2   Care shall be taken to avoid distortion, bending, or cracking of specimens during and after removal from pavements or mold. Specimens shall be stored in a safe, cool place. If prepared cores are not immediately tested, they shall be carefully stored on a flat surface, (surface side down) avoiding exposure to excessive heat.

   8.3   Specimens shall be free of foreign materials such as seal coat, tack coat, foundation material, soil, paper, or foil. The bottom of a core from a pavement placed over aggregate base, crushed and shaped base or rubblized base shall be sawed. When any of these materials are visually evident, they shall be removed by wet sawing being careful not to remove any more of the material to be tested than necessary. Cores shall be sawn at the tack line/lines when applicable. Rinse any remaining loose material.

   8.4   If desired, specimens may be separated from other pavement layers by sawing or other satisfactory means.

9. Procedure

   9.1   For Core Specimens to Determine In-Place Density: The sequence of testing is: in water, saturated-surface dry, dry.

          9.1.1   *Mass of Specimen in Water* - Immerse the specimen, sawed surface facing down, in a water bath at 77 °F ± 1.8 °F (25 °C ± 1 °C) and shake gently to remove air. The immersion time shall be 3 to 5 minutes. Weigh the specimen in water and designate this mass as "C". If the temperature of the specimen differs from the temperature of the water bath by more than 2°C, the specimen shall be immersed in the water bath for 10 to 15 minutes instead of 3 to 5 minutes.

9.1.2 *Mass of Saturated Surface-Dry Specimen in Air* - Carefully lift specimen with sawed surface facing down, place on damp towel and quickly blot all surfaces to obtain a saturated surface dry condition. Weigh the specimen in air and designate this mass as B.

9.1.3 *Mass of Oven-Dry Specimen* - Thoroughly dry the specimen to constant mass (mass repeats within 0.1%) at 230 °F ± 9 °F (110 °C ± 5 °C). Record the checks on mass. (Note: 12 to 15 hours is usually sufficient.) Allow the specimen to cool and weigh in air. Designate this mass as A.

9.2 For Gyratory and Marshall Specimens:

9.2.1 *Mass of Dry Specimen in Air* – Allow sample to reach ambient temperature. Weigh the specimen. Designate this mass as A.

9.2.2 *Mass of Specimen in Water* - Immerse the specimen in a water bath at 77 °F (25 °C) and shake gently to remove air. The immersion time shall be 3 to 5 minutes. Weigh the specimen in water and designate this mass as "C". If the temperature of the specimen differs from the temperature of the water bath by more than 2 °C, the specimen shall be immersed in the water bath for 10 to 15 minutes instead of 3 to 5 minutes.

9.2.3 *Mass of Saturated Surface-Dry Specimen in Air* - Carefully lift specimen, place on damp towel and quickly blot all surfaces to obtain a saturated surface dry condition. Weigh the specimen in air and designate this mass as B.

10. Calculation

10.1 *Calculate the bulk specific gravity of the specimen as follows*:

Bulk sp gr = A / (B - C)

where:

A = mass of the dry specimen in air, g,
(B-C) = mass of the volume of water for the volume of the specimen at 77 °F
(25 °C),

B = mass of the saturated surface-dry specimen in air, g, and
C = mass of the specimen in water, g.

10.2 Calculate the density of the specimen as follows:
Density = Bulk sp gr x 997.0 (or 62.24)

Where:

997.0 = density of water in kg/m^3 at 25°C (0.9970 g/cm^3)

10.3 This test method has been written using the absolute system for density (kilograms per meter cubed) in SI units. The conversion to the gravitational system of unit weight in pounds per foot cubed and the recording of density in pounds force per foot cubed is acceptable with this test method.

11. Report

11.1 *Report the following:*

- Bulk specific gravity of the mixture to three decimal places as: bulk specific gravity at 77 °F (25 °C),
- Density of the mixture with four significant figures in kg/m^3 or lb/ft^3 as: density at   77 °F (25 °C),
- Type of mixture and size of sample.